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(54) **DIAGNOSTIC SYSTEM AND METHOD FOR AN ELECTRIC POWER STEERING SYSTEM**

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H02P 29/02 (2006.01)

(52) **U.S. Cl.**
CPC ***H02P 29/021*** (2013.01)

(58) **Field of Classification Search**
USPC 701/41, 42, 43; 318/54, 65, 434; 324/177, 143, 765.01
See application file for complete search history.

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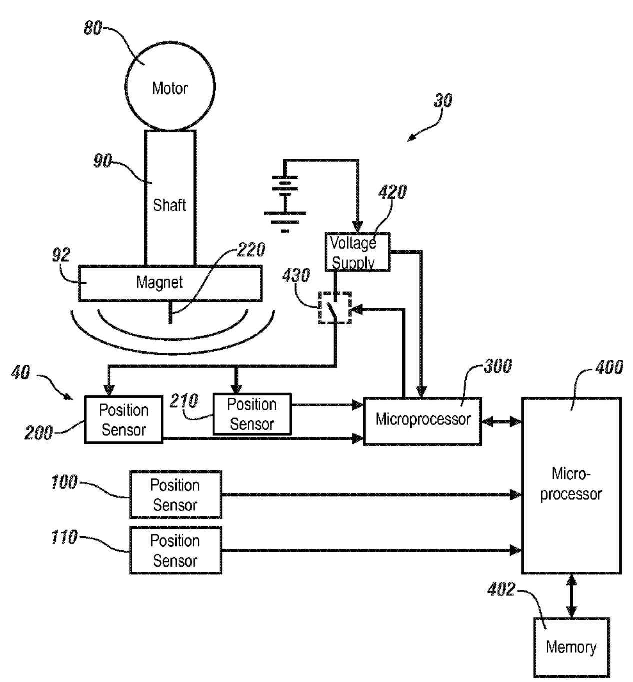
(57) **ABSTRACT**

A diagnostic system and method for an electric power steering system are provided. The diagnostic system includes a first microprocessor that determines a first relative position value indicating the relative rotational position of the rotatable shaft at the first time based on the signals from first and second position sensors. A second microprocessor determines a second relative position value indicating the relative rotational position of the rotatable shaft at the first time based on the signals from third and fourth position sensors. The first microprocessor determines whether the first relative position value is an acceptable value based on a difference between the first relative position value and the second relative position value.

13 Claims, 4 Drawing Sheets



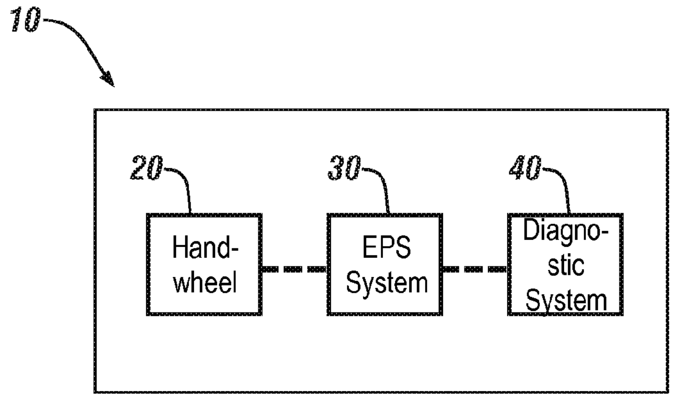

10
20
30
40
Hand-
wheel
EPS
System
Diagno-
stic
System

FIG. 1

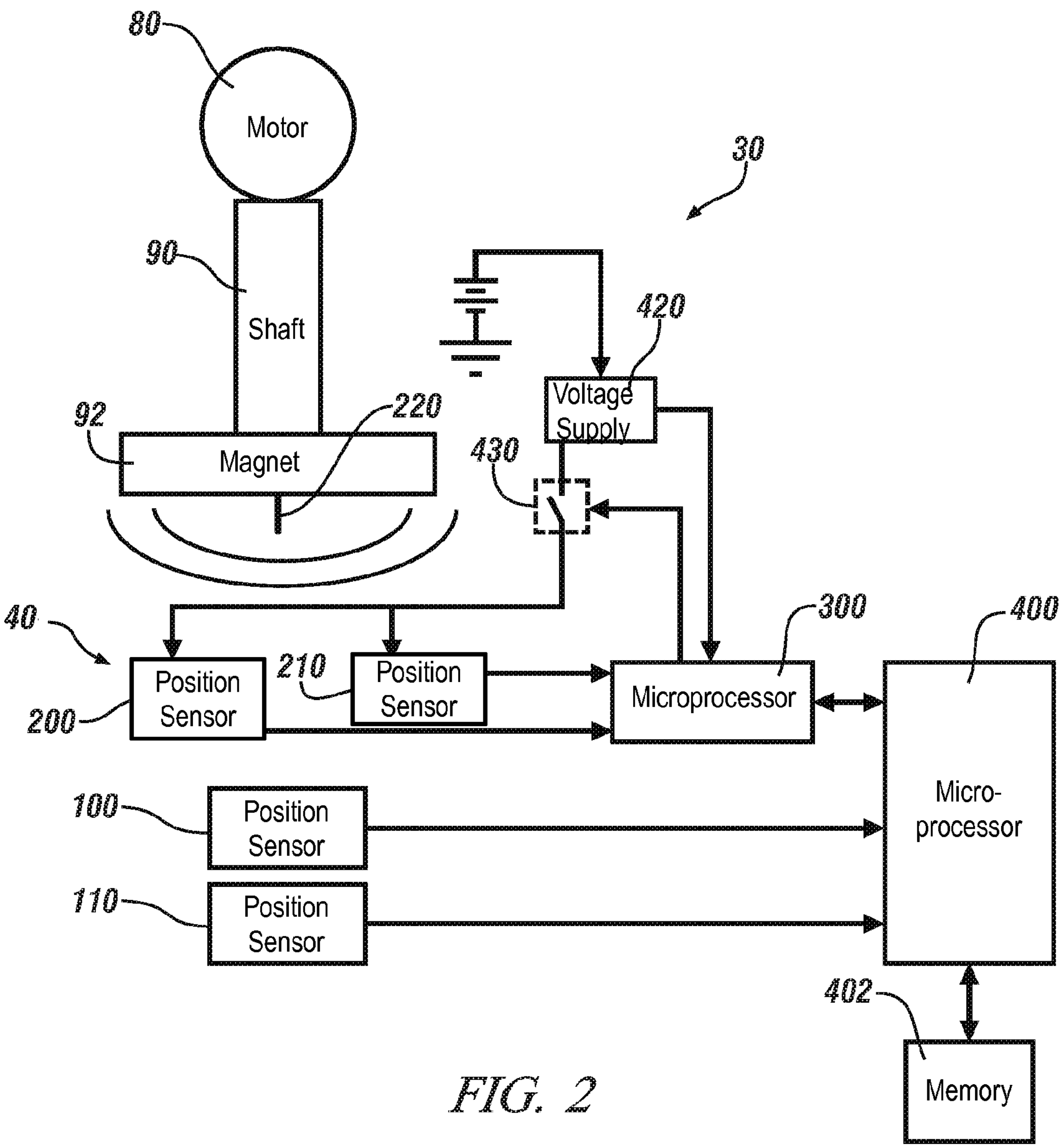

80
Motor
30
90
Shaft
420
92
220
Magnet
Voltage
Supply
430
40
Position
Sensor
210
Position
Sensor
Microprocessor
300
400
200
100
Position
Sensor
Micro-
processor
110
Position
Sensor
402
Memory

FIG. 2

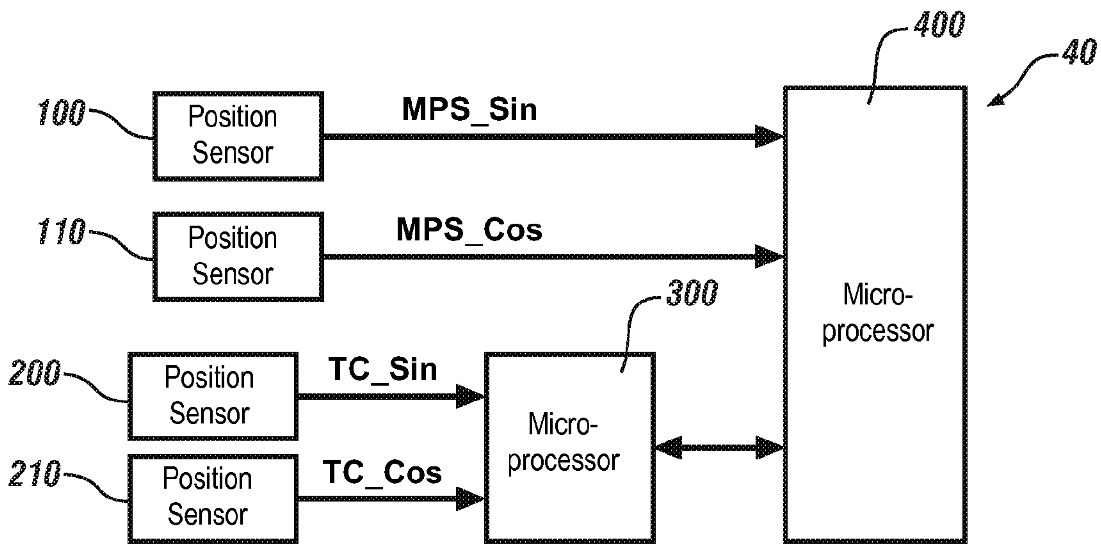

400
40
100
Position Sensor
MPS_Sin
110
Position Sensor
MPS_Cos
Micro-processor
300
200
Position Sensor
TC_Sin
Micro-processor
210
Position Sensor
TC_Cos

FIG. 3

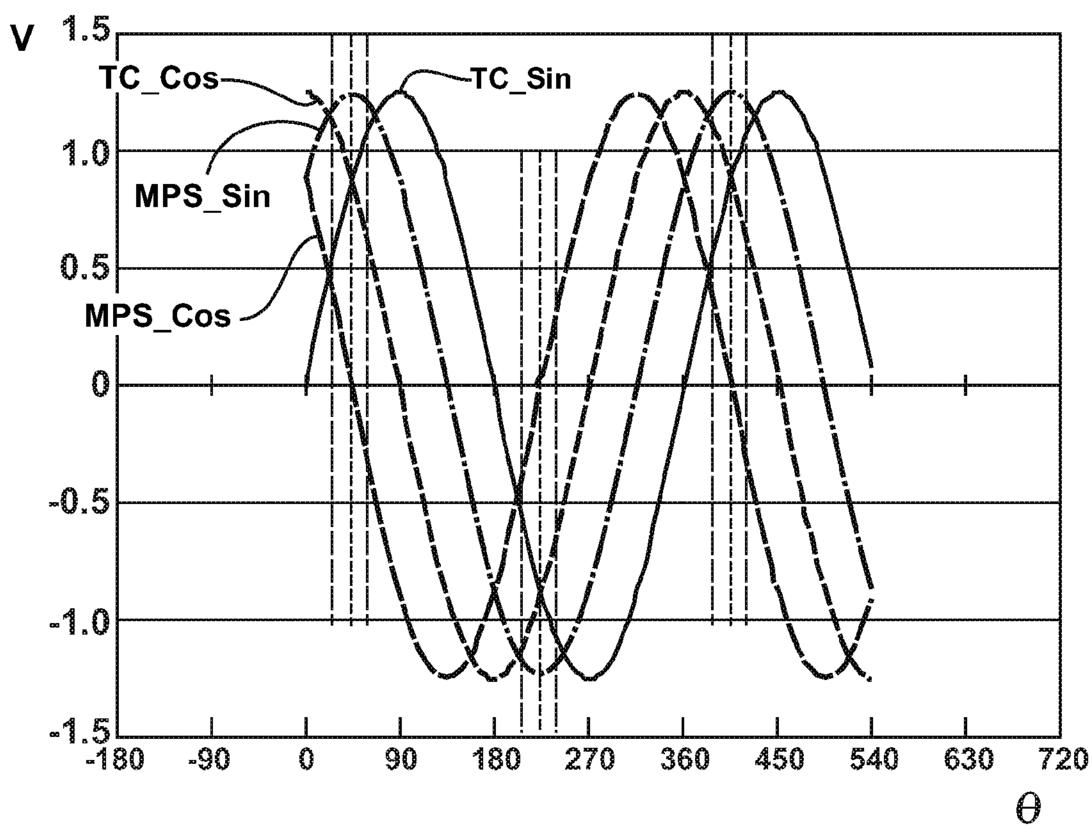

V
1.5
1.0
0.5
0
-0.5
-1.0
-1.5
TC_Cos
TC_Sin
MPS_Sin
MPS_Cos
-180
-90
0
90
180
270
360
450
540
630
720
θ

FIG. 4

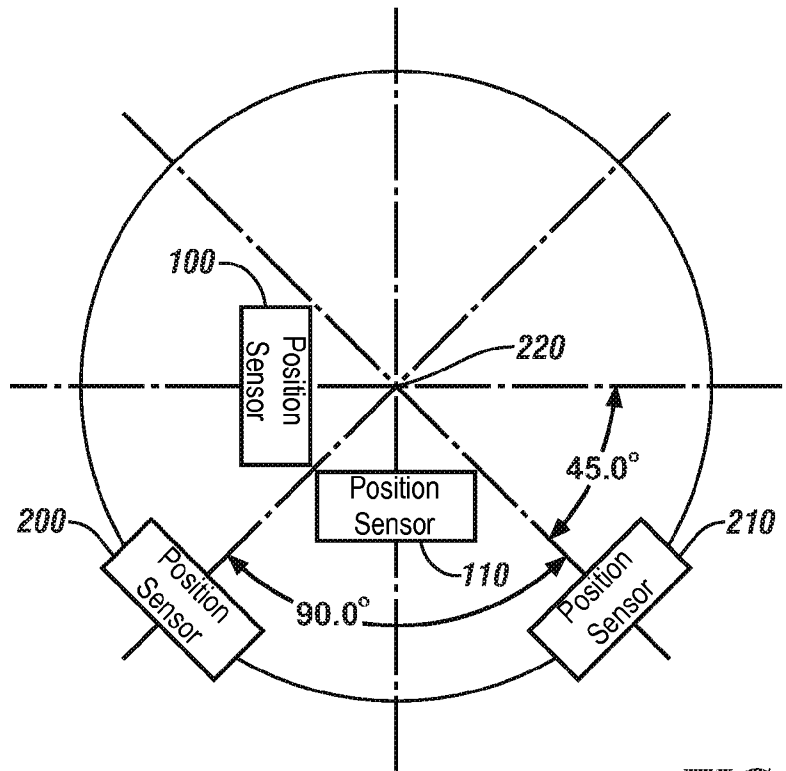

100
Position Sensor
220
45.0°
Position Sensor
200
Position Sensor
210
Position Sensor
110
90.0°

FIG. 5

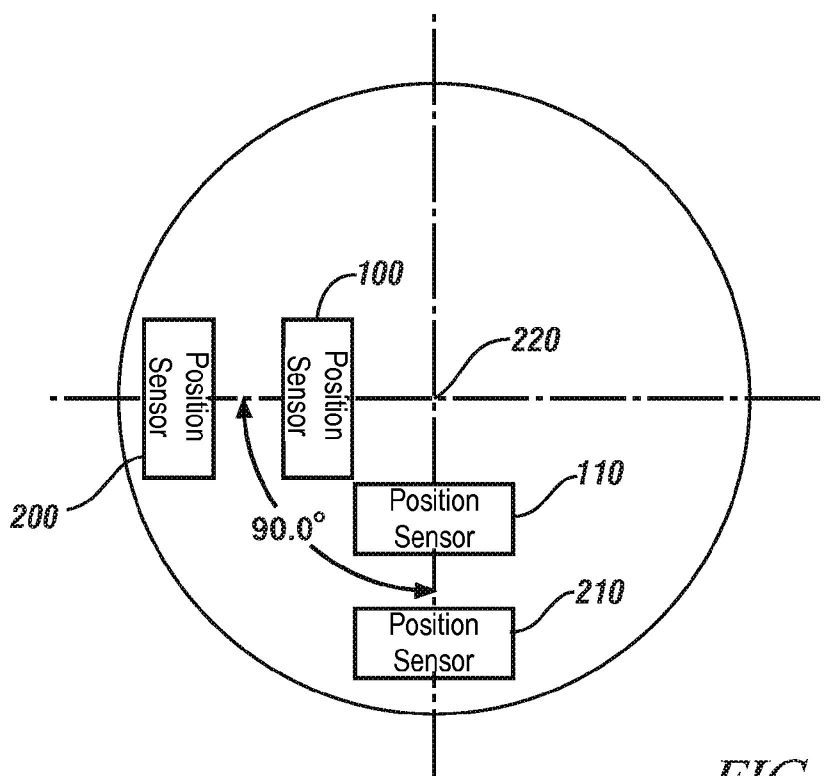

100
220
Position Sensor
Position Sensor
200
110
Position Sensor
90.0°
210
Position Sensor

FIG. 6

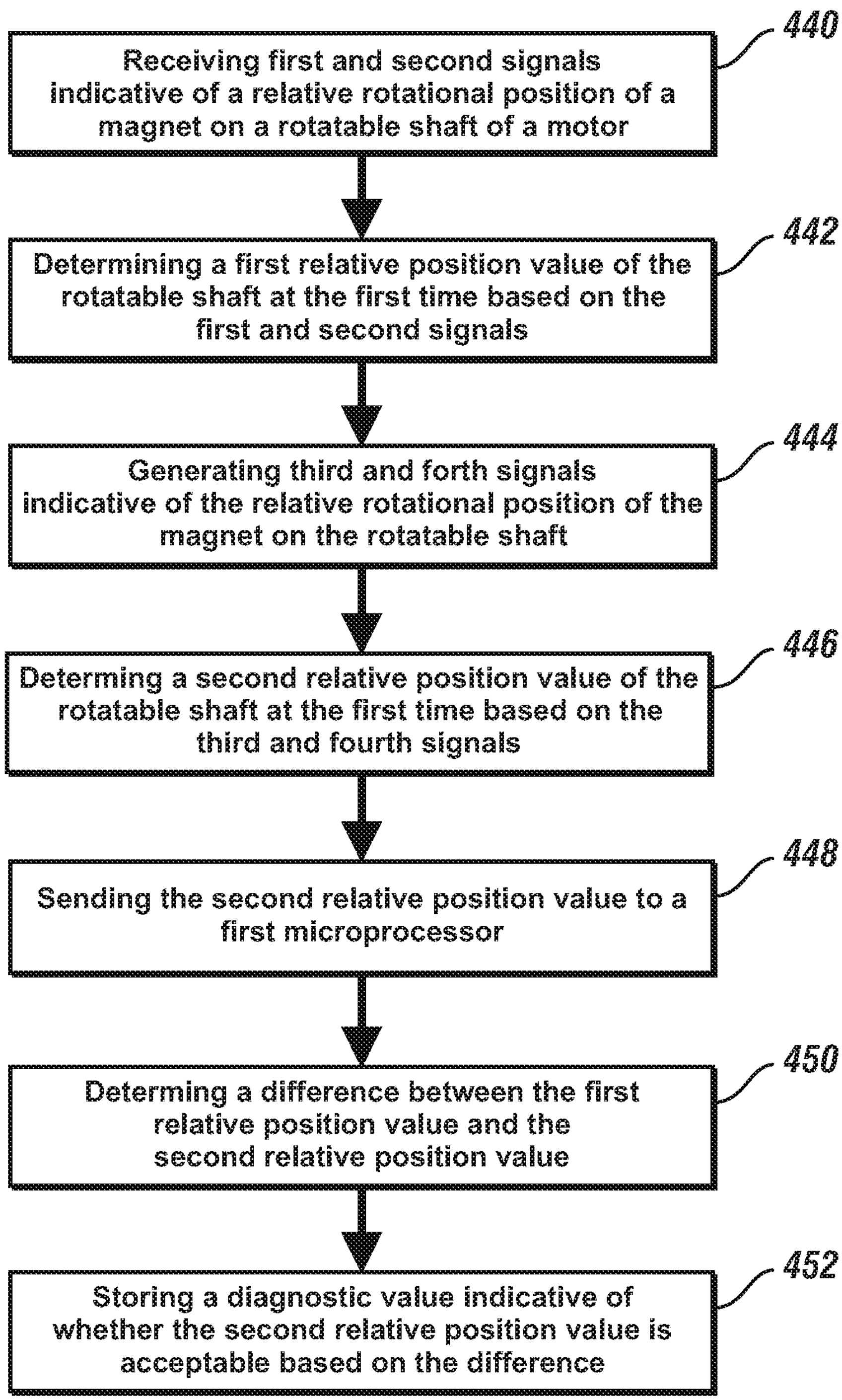

440
Receiving first and second signals indicative of a relative rotational position of a magnet on a rotatable shaft of a motor
442
Determining a first relative position value of the rotatable shaft at the first time based on the first and second signals
444
Generating third and forth signals indicative of the relative rotational position of the magnet on the rotatable shaft
446
Determing a second relative position value of the rotatable shaft at the first time based on the third and fourth signals
448
Sending the second relative position value to a first microprocessor
450
Determing a difference between the first relative position value and the second relative position value
452
Storing a diagnostic value indicative of whether the second relative position value is acceptable based on the difference

FIG. 7

DIAGNOSTIC SYSTEM AND METHOD FOR AN ELECTRIC POWER STEERING SYSTEM

CROSS-REFERENCES TO RELATED APPLICATIONS

This patent application claims priority to U.S. Provisional Patent Application Ser. No. 61/416,671 filed Nov. 23, 2010, which is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

The subject invention relates to a diagnostic system and a diagnostic method for an electric power steering system.

BACKGROUND

Position sensors have been utilized to determine a motor position. However, the position sensors may have degraded operation.

Accordingly, it is desirable to provide a diagnostic system for an electronic power steering system that detects degraded position sensors.

SUMMARY OF THE INVENTION

A diagnostic system for an electric power steering system in accordance with an exemplary embodiment is provided. The diagnostic system includes a first microprocessor configured to receive first and second signals from first and second position sensors, respectively, disposed in a motor of the electric power steering system. The first and second signals are indicative of a relative rotational position of a magnet on a rotatable shaft of the motor. The first microprocessor is further configured to determine a first relative position value indicating the relative rotational position of the rotatable shaft at the first time based on the first and second signals. The diagnostic system further includes third and fourth position sensors disposed proximate to the rotatable shaft and offset from the first and second position sensors. The third and fourth position sensors are configured to generate third and fourth signals, respectively, indicative of the relative rotational position of the magnet on the rotatable shaft. The diagnostic system further includes a second microprocessor configured to receive the third and fourth signals and to determine a second relative position value indicating the relative rotational position of the rotatable shaft at the first time based on the third and fourth signals. The second microprocessor is further configured to send the second relative position value to the first microprocessor. The first microprocessor is further configured to determine a difference between the first relative position value and the second relative position value. The first microprocessor is further configured to store a diagnostic value in a memory device indicative of whether the second relative position value is acceptable based on the difference between the first relative position value and the second relative position value.

A diagnostic method for an electric power steering system in accordance with another exemplary embodiment is provided. The method includes receiving first and second signals from first and second position sensors, respectively, disposed in a motor of the electric power steering system, utilizing a first microprocessor. The first and second signals are indicative of a relative rotational position of a magnet on a rotatable shaft of the motor. The method further includes determining a first relative position value indicating the relative rotational position of the rotatable shaft at the first time based on the first and second signals utilizing the first microprocessor. The method further includes generating third and fourth signals from third and fourth position sensors, respectively, disposed proximate to the rotatable shaft and offset from the first and second position sensors. The third and fourth signals are indicative of the relative rotational position of the magnet on the rotatable shaft. The method further includes receiving the third and fourth signals at a second microprocessor and determining a second relative position value indicating the relative rotational position of the rotatable shaft at the first time based on the third and fourth signals, utilizing the second microprocessor. The method further includes sending the second relative position value from the second microprocessor to the first microprocessor. The method further includes determining a difference between the first relative position value and the second relative position value, utilizing the first microprocessor. The method further includes storing a diagnostic value in a memory device indicative of whether the second relative position value is acceptable based on the difference between the first relative position value and the second relative position value, utilizing the first microprocessor.

The above features and advantages and other features and advantages of the present invention are readily apparent from the following detailed description of the invention when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features, advantages and details appear, by way of example only, in the following detailed description of embodiments, the detailed description referring to the drawings in which:

FIG. **1** is a block diagram of a vehicle having a handwheel, an electric power steering system, and a diagnostic system in accordance with an exemplary embodiment;

FIG. **2** is a block diagram of the electric power steering system and the diagnostic system of FIG. **1**;

FIG. **3** is a block diagram of a portion of the diagnostic system of FIG. **1**;

FIG. **4** is a schematic of output signals generated by position sensors utilized in the diagnostic system of FIG. **3**;

FIG. **5** is a schematic illustrating exemplary positions of position sensors utilized in the diagnostic system of FIG. **3** in accordance with an exemplary embodiment;

FIG. **6** is a schematic illustrating other exemplary positions of position sensors utilized in the diagnostic system of FIG. **3** in accordance with another exemplary embodiment; and

FIG. **7** is a flowchart of a diagnostic method in accordance with another exemplary embodiment.

DESCRIPTION OF THE EMBODIMENTS

Referring to FIGS. **1** and **2**, a vehicle **10** having a handwheel **20**, an electric power steering system **30**, and a diagnostic system **40** in accordance with an exemplary embodiment is illustrated.

The handwheel **20** is operably coupled to the electric power steering system **30**. Rotation of the handwheel **20** induces the electric power steering system **30** to cause rotation of a rotatable motor shaft **90** operably coupled to a rack-and-pinion assembly to move an operational position of vehicle wheels.

Referring to FIGS. **2**-**4**, the electric power steering system **30** includes a motor **80** having a rotatable shaft **90**, a magnet **92** disposed on the shaft **90**, first and second position sensors **100**, **110**, and a first microprocessor **400**. The first microprocessor **400** is also part of the diagnostic system **40**. In one embodiment, the rotatable shaft **90** is operably coupled via a gear assembly to a rack-and-pinion assembly for controlling an operational position of vehicle wheels.

The first microprocessor **400** is configured to receive first and second signals (MPS_Sin, MPS_Cos) from first and second position sensors **100**, **110**, respectively, disposed in the motor **80** of the electric power steering system **30**. The first and second signals are indicative of a relative rotational position of the magnet **92** on the rotatable shaft **90** of the motor **80**. The first microprocessor **400** is further configured to determine a first relative position value (P**1**) indicating the relative rotational position of the rotatable shaft **90** at the first time based on the first and second signals. In one exemplary embodiment, the first and second position sensors **100**, **110** are Hall effect sensors. Of course, in alternative embodiments other position sensors known to those skilled in art could be utilized.

The diagnostic system **40** includes third and fourth position sensors **200**, **210**, a second microprocessor **300**, the first microprocessor **400**, a voltage supply **420** and a controllable switch **430**. The diagnostic system **40** is provided to determine whether the third and fourth position sensors **200**, **210** are outputting acceptable position signals or degraded position signals. In particular, the diagnostic system **40** determines a difference between a relative rotational position value of the shaft **90** determined from signals from the first and second position sensors **100**, **110**, and a second relative rotational position value of the shaft **90** determined from signals from the third and fourth position sensors **200**, **210**. If a difference between the first and second relative position values is less than a threshold value, the second relative position value is an acceptable value as will be explained in greater detail below. Otherwise, the second relative position value is not an acceptable value as will be explained in greater detail below.

The third and fourth position sensors **200**, **210** are disposed proximate to the rotatable shaft **90** and angularly offset from the first and second position sensors **100**, **110** relative to an axis **220** of the motor **80**. The microprocessor **300** is configured to generate a control signal to induce the switch **430** to have a closed operational position for supplying an operational voltage from the voltage supply **420** to the positions sensors **200**, **210**. Thereafter, when the third and fourth position sensors **200**, **210** are activated, the position sensors **200**, **210** are configured to generate the third and fourth signals (TC_Sin, TC_Cos), respectively, indicative of the relative rotational position of the magnet **92** on the rotatable shaft **90**. In one exemplary embodiment shown in FIG. **5**, the third and fourth position sensors **200**, **210** are disposed 90 degrees apart from one another about a central axis **220** of the rotatable shaft **90**. Of course, the sensors **200**, **210** could be disposed at other angles relative to the central axis depending upon a desired application.

The second microprocessor **300** is configured to receive the third and fourth signals from the third and fourth position sensors **200**, **210** and to determine a second relative position value (P**2**) indicating the relative rotational position of the rotatable shaft **90** at the first time based on the third and fourth signals. The second microprocessor **300** is further configured to send the second relative position value to the first microprocessor **400**.

The first microprocessor **400** is configured to determine whether the second relative position value (P**2**) is an acceptable value based on a difference between the first relative position value (P**1**) and the second relative position value (P**2**). In particular, the first microprocessor **400** determines that the second relative position value (P**2**) is an acceptable value if an absolute value of the calculated difference (e.g., absolute value (P**1**-P**2**)) is less than a threshold value. Alternately, the first microprocessor **400** determines that second relative position value (P**2**) is not an acceptable value if an absolute value of the calculated difference is greater than or equal to the threshold value. It should be noted that there will typically be an angular offset between the first relative position value (P**1**) and the second relative position value (P**2**), due to the physical placement of the first and second position sensors **100**, **110**, **200**, **210** which will be discussed in greater detail below.

Referring to FIGS. **3** and **4**, in one exemplary embodiment, the first, second, third, and fourth position sensors **100**, **110**, **200**, **210** output the first, second, third, and fourth signals MPS_Sin, MPS_Cos, TC_Sin, TC_Cos, respectively, as illustrated.

Referring to FIG. **5**, in one exemplary embodiment, the third and fourth position sensors **200**, **210** are positioned such that sensors **200**, **210** are disposed at a known angle, such as 45° or another calibrated angle, from the first and second position sensors **100**, **110**; and thus the output signals TC_Sin, TC_Cos are at a known offset angle, such as 45° or the other calibrated angle, from the output signals from the first and second position sensors **100**, **110**. As shown, the third and fourth position sensors **200**, **210** are angularly disposed 45 degrees from the position sensor **110** relative to the central axis **220** and 90 degrees apart from one another.

Referring to FIG. **6**, in an alternative embodiment, the position sensors **100**, **200** are positioned such that sensors **100**, **200** are disposed at an identical angle relative to the central axis **220**. Also, the position sensors **110**, **210** can be disposed at another angle relative to the central axis **220** that is offset 90° from the position of the sensors **100**, **200**, and thus the output signals TC_Sin, MPS_Sin would be in phase with one another and the output signals TC_Cos and MPS_Cos would be in phase with one another.

Referring to FIG. **7**, a flowchart of a diagnostic method for the electric power steering system **30** in accordance with another exemplary embodiment will be explained.

At step **440**, the first microprocessor **400** receives the first and second signals from first and second position sensors **100**, **110**, respectively, disposed in the motor **80** of the electric power steering system **30**. The first and second signals are indicative of a relative rotational position of the magnet **92** on the rotatable shaft **90** of the motor **80**.

At step **442**, the first microprocessor **400** determines a first relative position value (P**1**) indicating the relative rotational position of the rotatable shaft **90** at the first time based on the first and second signals. In one exemplary embodiment, the first relative position value (P**1**) is determined utilizing the following equation: first relative position value (P**1**)=ArcTan (first signal/second signal).

At step **444**, the third and fourth position sensors **200**, **210** generate third and fourth signals, respectively, indicative of the relative rotational position of the magnet **92** on the rotatable shaft **90**. The third and fourth position sensors **200**, **210** are disposed proximate to the rotatable shaft **90** and outside of the motor **80**.

At step **446**, the second microprocessor **300** receives the third and fourth signals and determines a second relative position value (P**2**) indicating the relative rotational position of the rotatable shaft **90** at the first time based on the third and fourth signals. In one exemplary embodiment, the second relative position value (P**2**) is determined utilizing the following equation: second relative position value (P**2**)=ArcTan (third signal/fourth signal).

At step **448**, the second microprocessor **300** sends the second relative position value (P**2**) to the first microprocessor **400**.

At step **450**, the first microprocessor **400** determines a difference between the first relative position value (P**1**) and the second relative position value (P**2**).

At step **452**, the first microprocessor **400** stores a diagnostic value in a memory device **402** indicative of whether the second relative position value (P**2**) is acceptable based on the difference between the first relative position value (P**1**) and the second relative position value (P**2**).

Referring to FIGS. **2**-**4**, an advantage of the diagnostic system **40** will now be explained. In particular, if only the microprocessor **300** and position sensors **200**, **210** were utilized, terminals of the position sensors **200**, **210** could be undesirably shorted together and the microprocessor **300** would not be able to determine the inaccuracy of the second relative position value (P**2**) in the motor angle region **1** shown in FIG. **4**. Also, if only the microprocessor **400** and position sensors **100**, **110** were utilized, terminals of the position sensors **100**, **110** could be undesirably shorted together and the microprocessor **400** would not be able to determine the associated inaccuracy of with the first relative positions value (P**1**). However, by utilizing the microprocessor **300** and position sensors **200**, **210**, and the microprocessor **400** and position sensors **100**, **110**, the first relative position value P**1** can be compared with the second relative position value P**2** to verify the accuracy of the second relative position value P**2**.

The diagnostic system **40** and the diagnostic method for the electric power steering system provide a substantial advantage over other system and methods. In particular, the diagnostic system **40** and the diagnostic method provide a technical effect of generating a diagnostic value indicative of whether a relative position value of a rotatable shaft is accurate.

While the invention has been described with reference to exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiments disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the present application.

What is claimed is:

1. A diagnostic system for an electric power steering system, comprising:

a first microprocessor configured to receive first and second signals from first and second position sensors, respectively, disposed in a motor of the electric power steering system, the first and second signals being indicative of a relative rotational position of a magnet on a rotatable shaft of the motor, the first microprocessor further configured to determine a first relative position value indicating the relative rotational position of the rotatable shaft at a first time based on the first and second signals;

third and fourth position sensors disposed proximate to the rotatable shaft and outside of the motor, the third and fourth position sensors configured to generate third and fourth signals, respectively, indicative of the relative rotational position of the magnet on the rotatable shaft;

a second microprocessor configured to receive the third and fourth signals and to determine a second relative

position value indicating the relative rotational position of the rotatable shaft at the first time based on the third and fourth signals;

the second microprocessor further configured to send the second relative position value to the first microprocessor; and

the first microprocessor further configured to determine a difference between the first relative position value and the second relative position value; and

the first microprocessor further configured to store a diagnostic value in a memory device indicative of whether the second relative position value is acceptable based on the difference between the first relative position value and the second relative position value.

2. The diagnostic system of claim **1**, wherein the second relative position value is acceptable if the difference is less than a threshold value.

3. The diagnostic system of claim **1**, wherein the second relative position value is not acceptable if the difference is greater than or equal to the threshold value.

4. The diagnostic system of claim **1**, wherein the third and fourth position sensors are disposed 90 degrees apart from one another about a central axis of the rotatable shaft.

5. The diagnostic system of claim **4**, wherein the third and fourth position sensors are angularly disposed 45 degrees from the first position sensor relative to the central axis and 90 degrees apart from one another.

6. The diagnostic system of claim **1**, wherein the third and fourth position sensors are angularly disposed at first and second angles, respectively, that are 90 degrees apart from one another relative to the central axis, and the first and second position sensors being disposed at the first and second angles, respectively.

7. The diagnostic system of claim **1**, wherein the first, second, third, and fourth position sensors are Hall effect sensors.

8. A diagnostic method for an electric power steering system, comprising:

receiving first and second signals from first and second position sensors, respectively, disposed in a motor of the electric power steering system, utilizing a first microprocessor, the first and second signals being indicative of a relative rotational position of a magnet on a rotatable shaft of the motor;

determining a first relative position value indicating the relative rotational position of the rotatable shaft at a first time based on the first and second signals utilizing the first microprocessor;

generating third and fourth signals from third and fourth position sensors, respectively, disposed proximate to the rotatable shaft and outside of the motor, the third and fourth signals being indicative of the relative rotational position of the magnet on the rotatable shaft;

receiving the third and fourth signals at a second microprocessor and determining a second relative position value indicating the relative rotational position of the rotatable shaft at the first time based on the third and fourth signals, utilizing the second microprocessor;

sending the second relative position value from the second microprocessor to the first microprocessor;

determining a difference between the first relative position value and the second relative position value, utilizing the first microprocessor; and

storing a diagnostic value in a memory device indicative of whether the second relative position value is acceptable based on the difference between the first relative position value and the second relative position value, utilizing the first microprocessor.

9. The diagnostic method of claim **8**, wherein the second relative position value is acceptable if the difference is less than a threshold value.

10. The diagnostic method of claim **8**, wherein the second relative position value is not acceptable if the difference is greater than or equal to the threshold value.

11. The diagnostic method of claim **8**, wherein the third and fourth position sensors are disposed 90 degrees apart from one another about a central axis of the rotatable shaft.

12. The diagnostic method of claim **11**, wherein the third and fourth position sensors are angularly disposed 45 degrees from the first position sensor relative to the central axis and 90 degrees apart from one another.

13. The diagnostic method of claim **8**, wherein the third and fourth position sensors are angularly disposed at first and second angles, respectively, that are 90 degrees apart from one another relative to the central axis, and the first and second position sensors being disposed at the first and second angles, respectively.

* * * * *